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(54) [Title of the Invention] EXPOSURE APPARATUS, EXPOSURE METHOD AND DEVICE MANUFACTURING METHOD

(57) [Abstract]

[Problem to be Solved] To make it possible to transfer a finer pattern on a substrate.

[Solution] When the wavelength of an energy line for exposure is changed, a part of lenses of a projection optical system is moved in an optical axis direction in order to prevent the projection magnification of a pattern image from becoming imprecise owing to the wavelength change.

[Scope of Claims for Patent]

[Claim 1] An exposure apparatus that exposes a substrate by irradiating a mask with an energy line and projecting an image of a pattern of the mask on the substrate via a projection optical system, the apparatus comprising:

an energy line source that emits the energy line and has a rough adjustment mechanism and a fine adjustment mechanism to set a wavelength of the energy line; and

a magnification adjusting means that moves a part of a lens of the projection optical system in an optical axis direction in order to prevent a projection magnification of a pattern image projected on the substrate from becoming imprecise by wavelength change of the energy line emitted from the energy line source.

[Claim 2] The apparatus according to claim 1, further comprising:

an illumination optical system for irradiating the mask with an energy line emitted from the energy line source, wherein

a secondary light source image in the illumination optical system is formed into a ring shape whose diameter and width are variable or switchable.

[Claim 3] The apparatus according to claim 1, further comprising:

an optical member that is placed on a pupil plane of the projection optical system and limits a light flux passing through the pupil plane to an annular shape.

[Claim 4] A device manufacturing method, using the apparatus according to any one of claims 1 to 3.

[Claim 5] An exposure method of exposing a substrate by irradiating a mask with an energy line and projecting an image of a pattern of the mask on the substrate via a projection optical system, the method comprising:

changing a wavelength of the energy line and also moving a part of a lens of the projection optical system in an optical axis direction in order to prevent a projection magnification of a pattern image projected on the substrate from becoming imprecise by wavelength change of the energy line.

[Claim 6] The method according to claim 5, wherein

the pattern of the mask includes a line pattern to be formed on the substrate and an auxiliary pattern arranged along a longitudinal direction of the line pattern for assisting formation of the line pattern.

[Claim 7] The method according to claim 6, wherein

the auxiliary pattern is arranged on both sides of the line pattern.

[Claim 8] A device manufacturing method, using the method according to any one of claims 5 to 7.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to an exposure apparatus and an exposure method that transfer an originally drawn pattern formed on a mask onto a sensitive substrate, in order to manufacture semiconductor devices, liquid crystal elements and the like.

[0002]

[Conventional Art] The manufacturing of semiconductor devices has progressed toward miniaturization and higher degree of

integration year by year, and a lithography process of increasingly thinner linewidth such as 1B-bit memory or 4B-bit memory has been required. In order to respond to this requirement, as an exposure apparatus currently used in a lithograph process, a reduction-projection type exposure apparatus (stepper) is the mainstream. Especially, a method is frequently used in which a reticle having an originally drawn pattern is reduced to around 15×15 mm square by a 1/5 reduction projection lens and a resist layer on a wafer is exposed with the reduced reticle.

[0003] In this stepper, the numerical aperture (N.A.) of the projection lens has been increasing year by year to raise the resolving power, and when the wavelength of an illumination light for exposure is 436nm (g-line), a projection lens with around N.A.=0.48 has been put into practice use. Increasing the numerical aperture of the projection lens in this manner means decreasing the effective depth of focus accordingly, and the depth of focus of a projection lens with N.A.=0.48 is, for example, not greater than ±0.8μm. That is, assuming that one shot area on a wafer has a size of 15×15 mm square, a surface (resist layer) of this entire area has to be accurately positioned within ±0.8μm (desirably, within ±0.2μm) with respect to a best image-forming plane of the projection lens.

[0004] Therefore, in order to cope with the insufficient depth of focus of the projection lens, a method has been proposed in which multiple exposures of a same reticle pattern are performed while a wafer is displaced in an optical axis direction with respect to the projection lens. This method increases the

apparent depth of focus of the projection lens and is one of effective exposure methods.

[0005]

[Problems to be Solved by the Invention] While this multiple-focus exposure method slightly reduces contrast of the best focus, it attempts to ensure contrast over a wide focus range. From the results of experiments and the like, the current situation is that this method is effective for a pattern for a so-called contact hole process in which the most part of a pattern surface of a reticle is a dark section (shielding section) and rectangular opening sections (transmissive sections) are dispersed, but is not effective for other patterns, in particular, a reticle pattern such as a wiring layer in which bright/dark linear patterns are repeated, compared with the case of the contact hole. This is because in the case of the reticle pattern like such a wiring layer or the like, when the focal position is changed, light intensity owing to a defocused image of a bright line section is given to a section that should intrinsically be a dark line on a wafer, and a consequence, the contrast drastically is degraded and dark film loss occurs. Further, in a projection exposure method, a period of a repetitive pattern capable of being transferred is limited to greater than or equal to a certain value owing to the performance of a projection lens. This value is also referred to as a resolution limit of the projection lens, and in the method currently put into practical use, a linewidth of a bright line and a dark line of a repetitive pattern is around 0.8μm on a wafer (4μm on a reticle) with a g-line, 1/5 reduction and N.A=0.45.

[0006] Consequently, even a linewidth of a pattern on a reticle is made thinner, a pattern with a linewidth thinner than the resolution limit is not normally exposed, and it is considered that the limit of lithograph by the projection exposure method is determined solely by the performance (resolving power) of a projection lens. In a proximity exposure method as well, it is difficult to make a repetition period of a bright line and a dark line on a mask be less than a certain value owing to diffraction phenomenon that occurs in accordance with a wavelength of an illumination light, and the wavelength is shortened as much as possible to cope with this situation. Therefore, a special energy line such as a soft X-ray is required.
[0007] The present invention has been made in view of these problems, and has as its first objective to enable finer patterns to be transferred without drastic increase in the numerical aperture of a projection optical system and drastic reduction in a wavelength of an illumination light. Further, the present invention has as its second objective to obtain a method with which finer patterns can be transferred regardless of a projection exposure method or a proximity exposure method.
[0008] Furthermore, the present invention has as its third objective to obtain a method with which effects by a multiple-focus exposure method can sufficiently be gained for most of patterns other than a contact hole pattern.
[0009]
[Means for Solving the Problems] In order to achieve the objectives described above, the invention according to claim 1 is an exposure apparatus that exposes a substrate by

irradiating a mask with an energy line and projecting an image of a pattern of the mask on the substrate via a projection optical system, the apparatus comprising: an energy line source (2) that emits the energy line and has a rough adjustment mechanism (203, 206) and a fine adjustment mechanism (204) to set a wavelength of the energy line; and a magnification adjusting means that moves a part of a lens of the projection optical system in an optical axis direction in order to prevent a projection magnification of a pattern image projected on the substrate from becoming imprecise by wavelength change of the energy line emitted from the energy line source.

[0010] Further, the invention according to claim 5 is an exposure method of exposing a substrate by irradiating a mask with an energy line and projecting an image of a pattern of the mask on the substrate via a projection optical system, the method comprising: changing a wavelength of the energy line and also moving a part of a lens of the projection optical system in an optical axis direction in order to prevent a projection magnification of a pattern image projected on the substrate from becoming imprecise by wavelength change of the energy line.

[0011] Now, an outline of separating a pattern into a plurality of patterns, aligning separated patterns with one another, and overlaying and exposing the separated patterns is described based on Fig. 1. In Fig. 1, whole patterns to be formed on a sensitive substrate are patterns PA and PB that are to be made within a chip (or shot) area CP, and pattern PA is a line-and-space (L/S) pattern bent at an angle of 90 degrees and pattern PB is a simple L/S pattern.

[0012] Each of patterns PA and PB are divided into three separated patterns, the separated patterns are formed on three reticles R1, R2 and R3, respectively. Reticles R1, R2 and R3 each have a light-shielding band SB corresponding to chip area CP formed, and inside the respective light-shielding bands, three patterns PTA1, PTA2 and PTA3 that are separated patterns of pattern PA and three patterns PTB1, PTB2 and PTB3 that are separated patterns of pattern PB are formed. On each of reticles R1, R2 and R3, marks for alignment RM1, RM2, RM3 and RM4 are provided and are used for alignment with marks WM1, WM2, WM3 and WM4 provided at chip area CP.

[0013] Although patterns PTA1, PTA2, PTA3, PTB1, PTB2 and PTB3 are shown in dark lines in the drawings, they are bright lines by light-transmissive sections in practice. After patterns PTA1 and PTB1 are positioned with chip area CP and exposed, the reticle is replaced with reticle R2 and patterns PTA2 and PTB2 are positioned with chip area CP and exposed, and subsequently, reticle R3 is positioned and patterns PTA3 and PTB3 are exposed.

[0014] Each of patterns PTB1, PTB2 and PTB3 is obtained by choosing linear patterns, of the L/S pattern of pattern PB, corresponding to bright lines with an interval of two liner patterns in between and grouping them, and a pitch of the line-and-space becomes threefold a pitch of a whole pattern (a duty becomes 1/3). Each pattern is separated such that there are no line that is bent at an angle of 90 degrees and continuous like each line of pattern PA, and this can be said for each of patterns PTA1, PTA2 and PTA3. A bent portion of 90-degrees is determined such that the ends of two lines orthogonal to each other (theses lines are respectively formed on different

reticles) partly overlap with each other. In this manner, in the case of the line-and-space pattern, bright lines next to each other are respectively formed on different reticles and the pattern density of bright lines in one reticle is decreased (1/3 in the case of Fig. 1), which allows the bright lines to be isolated.

[0015]

[Operation] Fig. 2(A) shows the case where a whole pattern Pa with a line-and-space shape is formed on a reticle R without separating the pattern, and Fig. 2(B) shows the case where a separated pattern Pb on which every other bright lines of pattern Pa are formed. In this case, widths of the bright lines of Pa and Pb are equally "d". When these reticles R are irradiated with an illumination light, a diffraction light is generated in directions corresponding to a pattern pitch P of each pattern. Assuming that a wavelength of the illumination light is λ, a diffraction angle θ of the n^{th} order diffraction light is expressed as $Sin\theta = n\lambda/P$ (in this case, n=0, ±1, ±2 and etc.). More specifically, for separated pattern Pb with a larger pattern and pitch, the diffraction angle of the same diffraction order is small, and as a consequence, the diffraction lights of the first or more diffraction orders that contribute to image-forming increase, which increases image contrast. Its example is described below.

[0016] Figs. 2(C), (D) and (E) show computed values (simulation) of an aerial image at the best focus of when a 0.4μm L/S (a repetitive pattern of a bright line and a dark line with a width of 0.4μm) is projected and exposed on a photosensitive substrate, using a g-line and a projection lens with N.A.=0.45

and σ=0.5. In this case, the σ value indicates a ratio between an area of an incident pupil of the projection lens and an area of a light source image. Fig. 2(C) figures intensity distribution of an aerial image in the case of exposure with one reticle, and a horizontal axis indicates a position (μm) on the photosensitive substrate with a center of a given bright line serving as an origin and a vertical line indicates relative intensity. Fig. 2(F) shows a sum of aerial image intensities obtained when two separated reticles are respectively exposed, and Figs. 2(D) and (E) figure intensity distributions of the aerial images of the separated patterns. As is obvious from this simulation, contrast of the aerial image is improved by separating a pattern and exposing separated patterns.

[0017] More specifically, in the case of a pattern with an L/S shape, even if a projection lens with the same numerical aperture is used, the larger number of high-order lights can be used for image-forming when exposure is performed with two or more separated patterns. This means that an image of a finer linear pattern is formed at the maximum with the resolution limit that is determined by the performance of the projection lens, which makes the image quality of a pattern (image quality of a resist pattern) favorable.

[0018] Furthermore, by using pattern PB on which the ratio of a bright section is lowered with respect to whole pattern Pa, even if the best image-forming plane of the projection lens and the photosensitive substrate surface are defocused, a defocused image of a dark section of pattern Pb is maintained consistently as the dark section and is not changed to a bright line, and accordingly only contrast of a bright line image is lowered.

Therefore, by performing the multiple-focus exposure method for every separated pattern, the effect of increasing the apparent depth of focus is obtained similarly to the case of a contact hole pattern.

[0019]

[Embodiments] Fig. 3 is a perspective view that shows a configuration of a projection type exposure apparatus (stepper) suitable for an embodiment of the present invention. Since the basic configuration of this stepper is similar to the one disclosed in, for example, Kokai (Japanese Unexamined Patent Application Publication) No. 62-145730, the basic configuration is briefly described below. An illumination light from a light source for exposure 2 passes through an illumination optical system 4 having a reticle blind (illumination field stop) and the like, and illuminates one reticle on a reticle stage 6. On reticle stage 6, four reticles R1, R2, R3 and R4 in this case can be mounted at the same time, and reticle stage 6 two-dimensionally moves in x and y directions. To reticle stage 6, movable mirrors 8x and 8y that each reflect a laser beam from a laser interferometer 10 for position measurement are fixed perpendicularly to each other. A reticle alignment system 12 is provided capable of detecting alignment marks RM1 to RM4 of the reticle and also detecting marks WM1 to WM4 on a wafer W. Therefore, alignment system 12 can be utilized in both the case where one of the four reticles is positioned with respect to the apparatus and the case where marks RM1 to RM4 and marks WM1 to WM4 are simultaneously detected and die-by-die alignment is performed. Note that although alignment system 12 is arranged only one location in Fig. 3,

alignment system 12 is placed at a plurality of locations corresponding to marks RM1, RM2, RM3 and RM4 shown in Fig. 1, respectively. Photoelectrical detection of marks RM1 to RM4 or marks WM1 to WM4 is performed by a mark detecting system 14.

[0020] An image of a pattern area of a reticle is formed and projected on chip area CP, which has been formed beforehand on wafer W, via a projection lens system 16. Wafer W is mounted on a wafer stage 26 that moves in the x and the y directions, and this wafer stage is configured of a Y stage 26y that moves in the y direction, an X stage 26x that moves in the x direction on y stage 26y and a Z stage 26z that finely moves in a projection optical axis direction (Z direction) on X stage 26x. On Z stage 26z, movable mirrors 28x and 28y that reflect laser beams from laser interferometers 30x and 30y are fixed perpendicular to each other.

[0021] To Z stage 26z, a fiducial mark FM is fixed so as to be at substantially the same height as wafer W. Driving of X stage 26x and Y stage 26y in the respective axis directions is performed by motors 27x and 27y. An image-forming correcting mechanism 18 is incorporated in projection lens system 16, and automatically corrects every moment optical properties (magnification, focal point, certain types of distortion and the like) of projection lens system 16 that vary depending on an energy accumulated state by incidence of an exposure light, environmental conditions and the like. Since image-forming correcting mechanism 18 is disclosed in detail in, for example, Kokai (Japanese Unexamined Patent Application Publication) No. 60-078454, the description thereof is omitted herein. This stepper is equipped with an alignment system by a TTL (Through

The Lens) method configured of an alignment optical system 20 that detects, from below reticle stage 6, the marks (such as WM1 to WM4) on wafer W only via projection lens system 16, and a mark detecting system 22 that photoelectrically detects mark optical information detected with alignment optical system 20, and an alignment system 24 by an off-axis method that is separately arranged closest to projection lens system 16.

[0022] Although not illustrated in Fig. 3, a focus sensor by an oblique incident light method is provided that detects the height position of the surface of wafer W with a high resolving power, similarly to the one disclosed in Kokai (Japanese Unexamined Patent Application Publication) No. 60-078454, and the focus sensor operates together with Z stage 26z, as an automatic focusing mechanism that makes the best image-forming plane of the projection lens system and the wafer surface constantly coincide with each other. Now, an optical relation between illumination optical system 4 and projection lens system 16 in the configuration in Fig. 3 is described using Fig. 4. Illumination optical system 4 is configured so as to project a secondary light source image (surface light source) in a pupil EP of projection lens system 16, and the so-called Kohler illumination method is employed. The surface light source image is set to be slightly smaller than a size of pupil EP. Now, focusing attention on one point of reticle R having whole pattern Pa, there exists a given solid angle θr/2 in illumination light IL that reaches this point. This solid angle θr/2 is kept also after the illumination light is transmitted through whole pattern Pa, and the illumination light enters projection lens system 16 as a light flux Da0 of 0^{th} order light. This solid

angle $\theta r/2$ of illumination light IL is also called a numerical aperture of the illumination light. Assuming that projection lens 16 is a both-side telecentric system, a chief ray 11 that passes through the center of pupil EP (the point which an optical axis AX passes through) is parallel to optical axis AX, on each of the reticle R side and the wafer W side. The light flux having passed though pupil EP as described above becomes an image-forming light flux ILm on the wafer W side and forms an image on one point on wafer W. In this case, when a reduction magnification of projection lens system 16 is 1/5, a solid angle $\theta w/2$ of light flux ILm has a relation of $\theta w = 5 \cdot \theta r$. The solid angle $\theta w/2$ is also called a numerical aperture of the image-forming light flux on wafer W. A numerical aperture on the wafer side of projection lens system 16 alone is set by a solid angle of light flux ILm obtained when the light flux passes though the overall pupil EP.

[0023] When whole pattern Pa is equivalent to the one shown in Fig. 2(A), diffraction lights Da1, Da2 and etc. of high-order that is higher than or equal to the 1^{st} order are generated. Some of these high-order lights are generated spreading to the outer side of 0^{th} light flux Da0 and some are generated being distributed on the inner side of 0^{th} light flux Da0. Especially, a part of the high-order light that is distributed to the outer side of 0^{th} light flux Da0 does not reach wafer W, because even if the part of the high-order light enters projection lens system 16, the part of the high-order light is excluded by pupil EP. Consequently, if the larger number of high-order diffraction lights are utilized for image-forming, a diameter of pupil EP has to be larger as much as possible, i.e., the

numerical aperture (N.A.) of projection lens system 16 is further increased. Alternatively, it is also possible to restrain a spread angle of high-order lights Da1, Da2 and etc. from pattern Pa to a small angle by decreasing the numerical aperture (solid angle $\theta r/2$) of illumination light IL (decreasing a diameter of the surface light source image). In this case, however, if the numerical aperture (solid angle $\theta w/2$) of image-forming light flux ILm of 0^{th} order on the wafer W side is extremely reduced, the intrinsic resolution performance is deteriorated. Furthermore, since in general the diffraction angle of the high-order light is uniquely determined depending on the pitch and the duty of pattern Pa, lights of higher order than a certain order, of the high-order diffraction lights, are excluded by pupil EP even if the solid angle $\theta r/2$ of illumination light IL can be reduced close to zero. In contrast, when the whole pattern is divided into a plurality of separated patterns as in the present embodiment, as is obvious from Fig. 2(B), the diffraction angle of high-order lights spreading to the outer side of the 0^{th} order light flux is kept to a small angle, and accordingly the high order lights can be made to pass through pupil EP without difficulty.

[0024] Meanwhile, in Fig. 3, four reticles R1 to R4 are mounted on the same reticle stage 6, and can be exchanged such that the center of an arbitrary reticle of these reticles is located on optical axis AX of projection lens system 16. The positioning accuracy of each reticle during this exchange can be very-high accuracy (e.g. ±0.02μm) because laser interferometer 10 is used. Therefore, if a positional relation among four reticles R1 to R4 is measured with high precision in advance, the reticles can

be positioned by moving reticle stage 6 based on only the coordinate measurement values of laser interferometer 10. Further, even if the positional relation among reticles R1 to R4 is not measured in advance, each of the reticles can be positioned with high precision using alignment system 12, mark detecting system 14, fiducial mark FM and the like.

[0025] Moreover, in the present embodiment, during exposure of each of reticles R1 to R4 that has a separated pattern, the multiple-focus exposure method is used together. Therefore, when one chip area (shot area) CP on wafer W is exposed using a given reticle, repetitive exposure should be performed at each of three focal positions, which are a height position Z0 of the wafer surface that is detected as the best focus point by the focus sensor by an oblique incident light method, a height position Z1 that is around 0.5μm higher than this position Z0, and a height position Z2 that is around 0.5μm lower than position Z0. Consequently, while a certain chip area CP is exposed with one reticle, the height of wafer W is vertically moved with a 0.5μm step by Z stage 26z.

[0026] The equivalent effect can be obtained by vertically moving the best image-forming plane (reticle conjugate plane) of projection lens system 16 itself using image-forming correcting mechanism 18, instead of vertically moving Z stage 26z during the exposure operation. In this case, as disclosed in Kokai (Japanese Unexamined Patent Application Publication) No. 60-078454, image-forming correcting mechanism 18 is based on a method in which a gas pressure within a sealed lens space in projection lens system 16 is adjusted, and therefore, an offset pressure value used to vertically move the image-forming

plane by around ±0.5μm can be added to the original pressure adjusting value for correction, during the exposure operation. On this operation, a combination of lens spaces needs to be selected with which only the focal plane is varied by the pressure offset and the magnification, the distortion and the like are not varied.

[0027] Furthermore, using the advantage that projection lens system 16 is both-side telecentric, the height position of the best image-forming plane can similarly be changed, by vertically moving the reticles. In general, in the case of reduction projection, when the defocus amount on the image side (wafer side) is calculated into a defocus amount on the object side (reticle side), the result depends on the square of the reduction magnification. Therefore, when the defocus of ±0.5μm is needed on the wafer side, $\pm 0.5 / (1/5)^2 = \pm 12.5$μm is needed on the reticle side, with the reduction magnification of 1/5.

[0028] Next, several examples of dividing the whole pattern into separated patterns are described with reference to Figs. 5, 6, 7 and 8, although an example is briefly explained above with reference to Fig. 1. Fig. 5 illustrates an example in which in the case where a whole pattern is a line-and-space pattern in which a bright line pattern PLc with a width of D1 and a dark line pattern PLs with a width of D2 (D2 ≈ D1) are alternately repeated as shown in Fig. 5(A), separated patterns as shown in Figs. 5(B) and (C) are respectively formed on two reticles. In both the separated pattern in Fig. 5(B) and the separated pattern in Fig. 5(C), every other bright line pattern PLc is formed, compared to the whole pattern. Between the two separated patterns, the positions of bright line patterns PLc

are complementary. In this case, while in the whole pattern a pitch is D1 + D2 (≈ 2D1) and a duty is D1 / (D1 + D2) ≈ 1/2, in the separated pattern a pitch is 2D1 + 2D2 (≈ 4D1) and a duty is D1 / (2D1 + 2D2) ≈ 1/4. Therefore, bright patterns PLc can be isolated on each reticle.

[0029] Fig. 6 shows a state where when a whole pattern has an L/S shape as in Fig. 6(A), bright line patterns PLc are not formed on different reticles respectively, but each bright pattern is separated into small rectangular bright sections PLd and the small rectangular bright sections are placed in a complementary manner as in Figs. 6(B) and (C). In this method, in both of two separated patterns, isolated rectangular bright sections PLd are set so as to be shifted from each other in a direction orthogonal to a pitch direction of the L/S. Consequently, focusing attention on an arbitrary rectangular bright section PLd, a dark section with a width (D1 + 2D2) exists on both sides in the pitch direction of the L/S, and a duty in the pitch direction is about 1/4.

[0030] Fig. 7 shows a state in which a linear pattern bent at a right angle as a whole pattern as shown in Fig. 7(A) is divided, at a bent portion, into two linear patterns PTe and PTf as shown in Figs. 7(B) and (C) in accordance with the respective directions. The insides of patterns PTe and PTf are transparent sections and their peripheries are shielding sections. In this case, when two patterns PTe and PTf are bright sections, the two patterns should be partly overlapped with each other at the bent portion. However, the parts to be overlapped should be set at an angle of about 45 degrees with respect to both longitudinal directions of two patterns PTe and PTf. Therefore,

the connection parts of patterns PTe and PTf should have, for example, a shape cut at an angle of 45 degrees, not at a right angle. As described above, when the linear pattern bent at an angle of 90 degrees is separated into two patterns PTe and PTf and overlay exposure of the two patterns is performed, image reproduction of, in particular, the bent portion on a resist becomes favorable, and the shape of an inside corner portion bent at an angle of 90 degrees is clearly exposed. A similar method can be applied to linear patterns bent at other angles. Furthermore, a pattern having an edge bent at an acute angle (not greater than 90 degrees), not a linear pattern, should be separated into two patterns depending on two directions of the edge.

[0031] Fig. 8 shows the case where a whole pattern that is T-shaped as shown in Fig. 8(A) is separated into two linear patterns PTg and PTh depending on directions as in Figs. 8(B) and (C). Assuming that linear patterns PTg and PTh are both bright sections, a tip of linear pattern PTg should have an isosceles triangle shape with a vertex of 90 or more degrees, and this triangle part should be made to overlap with a part of a linear edge of pattern PTh as shown in Fig. 8(C). By doing so, the corner portion with 90 degrees of the T-shaped pattern is very clear on a resist image and hardly gets rounder or the like.

[0032] Several examples of pattern separation are shown above, and regarding whole pattern PA shown in Fig. 1, the method shown in Fig. 5 and the method shown in Fig. 7 are used together to divide the whole pattern into a plurality of separated patterns PTA1, PTA2 and PTA3. Incidentally, the number of separated

patterns should be two or more, and is not limited in particular. However, if the number of separated patterns (reticles) is large, errors during overlay exposure are accumulated accordingly, which is also a disadvantage in terms of throughput.

[0033] Further, while the respective separated patterns are formed on different reticles R1 to R4, it is also possible that a plurality of pattern areas of a same size are arranged on one large glass substrate, and separated patterns are respectively arranged in the pattern areas, as disclosed in Kokai (Japanese Unexamined Patent Application Publication) No. 62-145730. Next, a typical sequence of the present embodiment is described with reference to Fig. 9.

[0034] [step 100] First of all, each of reticles R1 to R4 having separated patterns is mounted on reticle stage 6, each of reticles R1 to R4 is accurately positioned on reticle stage 6 using alignment system 12. Especially, a rotation error of each of reticles R1 to R4 is reduced with sufficient precision. Therefore, a fine rotation mechanism is provided at a section that holds each of reticles R1 to R4 on reticle stage 6. However, a mechanism that finely moves each of reticles R1 to R4 in the x and the y directions can be omitted. This is because the coordinate position of reticle stage 6 itself is precisely controlled by laser interferometer 10, and therefore, each coordinate value, obtained when reticle stage 6 is positioned such that marks RM1 to RM4 of each of reticles R1 to R4 are detected with alignment system 12, can be stored. Actually, a reference for rotation of reticles R1 and R2 is a coordinate system set by laser interferometers 30x and 30y on the wafer stage side, and therefore, it is necessary that fiducial mark

FM and marks RM1 to RM4 are detected with alignment system 12 and the rotation errors of reticles R1 to R4 are controlled to be zero on the coordinate system on the wafer stage side. Such an alignment method regarding the rotation of reticles is disclosed in detail in, for example, Kokai (Japanese Unexamined Patent Application Publication) No. 60-186845.

[0035] [step 101] Next, an opening shape and a size of a reticle blind serving as an illumination field stop provided in illumination optical system 4 are set so as to coincide with light-shielding bands SG of the reticles.

[0036] [step 102] Subsequently, wafer W coated with a photoresist is loaded on a wafer stage, and alignment (global alignment) of the entire wafer is performed by detecting marks arranged at several chip areas CP on wafer W using alignment system 24 by an off-axis method or alignment optical system 20 by a TTL method, and a positional relation in the x-y plane between an array coordinate of chip areas CP on wafer W and optical axis AX of projection lens system 16 (a center point of a pattern area of the reticle) is set. When exposure on wafer W is a first print, marks WM1 to WM4 do not exist and accordingly step 102 is omitted.

[0037] [step 103] Next, the number of separated patterns, i.e., a pattern umber n corresponding to the number of reticles, and a chip number m corresponding to the number of chip areas CP to be exposed on wafer W are registered in a main controller that includes a computer. In this case, the pattern number n is set to any one of the number A of reticles, and the chip number m is set to be 1 in an initial state with 9 as the maximum number.

[0038] [step 104] Next, reticle stage 6 is precisely positioned such that a reticle corresponding to the pattern number n is located directly above projection lens system 16.

[0039] [step 105] Then, stepping movement of the wafer stage is performed based on the chip number m, and m^{th} chip area CP to be exposed is positioned immediately under projection lens system 16. At this point, the center of the n^{th} reticle and the center of m^{th} chip area CP are aligned to be normally within a range of around ±1μm in accordance with results obtained at the time of the global alignment.

[0040] [step 106] Next, assuming that die-by-die alignment is executed, positional deviations of marks WM1 to WM4 arranged at chip area CP with respect to reticle marks RM1 to RM4 are precisely measured using alignment optical system 12 or alignment optical system 20, and one of wafer stage 26 and reticle stage 6 is finely moved until the positional deviations fall within a permissible range.

[0041] Incidentally, instead of performing the die-by-die alignment with alignment optical system 20 by a TTL method or alignment optical system 12, it is also possible to employ another method such as an Enhanced Global Alignment (E. G. A.) method in which positions of marks WM1 to WM4 of three to nine chip areas CP on wafer W are measured and the stepping positions of all the chip areas are obtained by a statistical computation method based on the measurement values, as disclosed in Kokai (Japanese Unexamined Patent Application Publication) No. 61-044429.

[0042] [step 107] Next, exposure is performed on m^{th} chip area CP with the n^{th} reticle, and in this case, the multiple-focus

exposure method is applied to each chip area, and therefore, first of all, a defocus sensor by an oblique incident light method is operated for the chip area, and the height position of the chip area surface with respect to the best image-forming plane is precisely measured. Then, after the chip area is adjusted to the best focus position by Z stage 26z, a pattern of the reticle is exposed with around 1/3 of a normal exposure dose. Next, for example, in the case where a position at which an image of an L/S pattern of 0.5μm is accurately formed on wafer W is assumed to be the best focus position, Z stage 26z is offset to each of two positions that are changed from this height position by around +0.5μm and -0.5μm, and exposure is performed with 1/3 of the exposure dose at each height position. More specifically, in the present embodiment, triple exposures are performed at three positions in total that are the best focus point and the points upper and lower from the best focus point. While the exposure dose during each exposure of the multiple exposures may be around 1/3 of the normal exposure dose, the exposure dose should be minutely adjusted. Incidentally, when the best image-forming plane itself is vertically moved using image-forming correcting mechanism 18, it is also possible that exposure is performed while continuously moving the image plane between ±0.5μm instead of fixing the image plane position in a step-by-step method. In this case, a shutter provided in illumination optical system 4 is opened only once for one chip area CP, which is so advantageous in terms of throughput.

[0043] [step 108] When exposure of the m^{th} chip area has been completed, the set value of m is incremented by one.

[0044] [step 109] Here, whether or not exposure of all the chip areas on wafer W has been completed is judged. Since the maximum value of m is set to be 9, if m is greater than or equal to 10 at this point, the procedure proceeds to the next step, step 110, and if m is less than or equal to 9, the procedure returns to step 105 and the stepping is performed to a next chip area.

[0045] [step 110] When the n^{th} reticle has been exposed on wafer W, the wafer stage is re-set to an exposure position at which exposure on a first chip area is performed, and the chip number n is set to be 1.

[0046] [step 111] Here, if all the reticles of the separated patterns that have been prepared are exposed, exposure on one wafer has been completed. If the reticle(s) remain(s), the procedure proceeds to step 112.

[0047] [step 112] Next, the pattern number n is changed to another number corresponding to another reticle, and the procedure returns to step 104 again, and similar operations are repeated. Of the steps described above, it goes without saying that step 106 is also omitted besides previous step 102 when the first print is performed.

[0048] As described above, the processing of wafer W is sequentially performed, and when the processing of a plurality of wafers which have undergone the same process is performed, such a sequence can be employed that exposure of all the wafers in a lot is performed with one reticle, reticle replacement is performed, and then exposure of all the wafers in the lot is performed with a next reticle. Further, when the die-by-die alignment is performed in step 106, by commonly using a mark

of one type arranged at chip areas CP during alignment with each of reticles R1 to R4, a relative positional deviation among patterns of the respective reticles that are transferred on wafer W can be reduced to the minimum.

[0049] Moreover, when the E. G. A. method is employed, there is a possibility that drift of each of the alignment systems, drive systems and the like during the exposure sequence causes problems, but the drift can immediately be corrected even if the drift occurs, by checking the drift on every reticle replacement using fiducial mark FM or every wafer exposure completion.

[0050] In the present embodiment as described above, since multiple exposures of each of the separated patterns that have been isolated are performed at a plurality of focal positions , the increase in resolution limit and the increase in depth of focus can both be obtained. The resolution limit in this case means the limit at which bright lines and dark lines cannot be favorably separated and resolved when a whole pattern is transferred onto a resist due to diffraction phenomenon or the like because the whole pattern is dens like an L/S shape, and is different from a theoretical resolving power of projection lens system 16 itself. In the present embodiment, since linear patterns in a whole pattern are separated to be isolated and then the isolated patterns are projected, fine linear patterns can be transferred using substantially the theoretical resolving power of projection lens system 16 at a maximum. This effect is similarly obtained also in the case where the multiple-focus exposure method is not used together, or more specifically, in the case where overlay exposure of reticles

R1 to R4 of the respective separated patterns is preformed while Z stage 26z is fixed at the best focus in step 107 shown in Fig. 9.

[0051] Next, a method of pattern separation according to a second embodiment of the present invention and an exposure method accompanying the method of pattern separation are described. Fig. 10(A) shows, in a frame format, a cross-section of an example of a circuit pattern configuration formed on wafer W, and minute protrusions and depressions are formed on the wafer surface in a latter half of the manufacturing. This minute protrusions and depressions become larger than the depth of focus (e.g. ±0.8μm) of projection lens system 16 in some cases. In Fig. 10(A), a resist layer PR is formed on the wafer surface, patterns Pr1, Pr2 and Pr4 are exposed on the protrusions on the wafer, and a pattern Pr3 is exposed on the depression. In this case, while all patterns Pr1 to Pr4 as transparent sections are formed on one reticle in the conventional exposure method, patterns Pr1, Pr2 and Pr4 to be exposed on the protrusions are formed as transmissive sections Ps1, Ps2 and Ps4 on a reticle R1 as shown in Fig. 10(B) and pattern Pr3 to be exposed on the depression is formed as a transmissive section Ps3 on a reticle R2 as shown in Fig. 10(C) in the present embodiment.

[0052] Then, when overlay exposure of reticles R1 and R2 is performed, for reticle R1, exposure is performed with the best image-forming plane of projection lens system 16 being made to coincide with the protrusion side on wafer W, and for reticle R2, exposure is performed with the best image-forming plane being made to coincide with the depression side. By doing so, all the patterns in chip area CP are exposed with extremely good

resolving power, which makes it possible to prevent local defocus from occurring affected by the protrusions and the depressions.

[0053] Further in the present embodiment, the multiple-focus exposure method described in the first embodiment can be used together during exposure of each of reticles R1 and R2. And, when a linear pattern is exposed covering across the depression and the protrusion on wafer W, the linear pattern should be separated in its longitudinal direction into a section covering the protrusion and a section covering the depression on the respective reticles. Further, it is also possible that the protrusions and the depression on wafer W are divided into three groups, three separated patterns are made, and exposure is performed separately at three focal positions. As a matter of course, the separation rules described with Figs. 5 to 8 can be used together.

[0054] Fig. 11 is a view that illustrates a pattern separating method according to a third embodiment. In recent years, inserting sub-space marks has been proposed for the purpose of accurately replicating and exposing a shape of a minute isolated pattern (such as a contact hole) and a corner edge formed on a reticle. Fig. 11(A) figures a minute rectangular opening section Pcm formed as a contact hole on a reticle, and a size of this opening section Pcm is reduced to 1 to 2μm square when opening section Pcm is exposed on a wafer. When opening section Pcm of this type is projected and exposed, a corner of 90 degrees is broken to be round on a resist in most cases. Therefore, a sub-space mark Msp with a small size (e.g. 0.2μm square on the wafer) enough not to be resolved by a projection optical

system is arranged in the vicinity of four corner portions of opening section Pcm.
[0055] In the case of forming sub-space marks Msp in addition to essential opening section Pcm as described above, it becomes difficult to form sub-space mark Msp on a conventional reticle when an array pitch of opening section Pcm is narrower. Meanwhile, in the case where every other opening section Pcm is formed together with sub-space mark Msp on a different reticle (or a different separated pattern) as in the present embodiment, a sufficient space (shielding section) exists around one opening section Pcm, and therefore, there is an advantage that the way of arranging sub-space mark Msp has degrees of freedom.
[0056] Fig. 11(B) shows the case where a linear sub-space mark Msp is arranged on both sides in the vicinity of an end of a line pattern PLm. When a whole pattern is divided into separated patterns, a sub-space mark Msp arranged with a rectangular or linear pattern to be exposed needs be formed always together with the separated pattern, on a reticle. Further, when one whole pattern (e.g. a bent linear pattern) is separated into a plurality of patterns and a corner edge is generated in each separated pattern, a sub-space mark may newly be arranged in the vicinity of the corner edge or the like.
[0057] Fig. 12 is a view that illustrates a pattern separating method according to a fourth embodiment. In the present embodiment, in addition to the effect described in each of the embodiments above, an effect can be obtained that a fine linewidth lithography that exceeds the resolution limit of a projection optical system is achieved. Fig. 12(A) shows an

example of a cross section of wafer W, which shows the case where thin line patterns Pr5 , Pr6 and Pr7 that extend in a direction orthogonal to the page surface are left as resist images on a resist layer PR.

[0058] Assuming that all the peripheries of pattern Pr5, Pr6 and Pr7 are exposed to light on resist layer PR, a pattern is divided into two separated patterns on two reticles as shown in Figs. 12(B) and (C). In Figs. 12(B) and (C), on each of the two reticles, light-shielding sections are formed that overlap with each other at patterns Pr5, Pr6 and Pr7. A width ΔD of the overlapping light-shielding section determines a linewidth of each of patterns Pr5, Pr6 and Pr7. As is obvious here, in the conventional method, in order to expose one dark line pattern corresponding to each of patterns Pr5, Pr6 and Pr7, the linewidth of each of patterns Pr5 to Pr7 is restricted by the performance and the like of a projection lens. However, in the present embodiment, a width of a dark section on each of separated patterns on two reticles is so wide and is hardly affected by diffraction. Therefore, width ΔD can be very small without being restricted by the performance of the projection lens, the diffraction and the like, and for example, a 0.4μm line pattern can be made using an exposure apparatus with a resolution limit of 0.8μm. In the case of the present embodiment, it is considered that the dimension accuracy of a pattern image to be transferred onto wafer W is deteriorated depending on each alignment accuracy of two reticles (respective separated patterns), alignment accuracy between respective chip areas CP on wafer W, a making error of pattern areas between the two reticles, and the like. However, the

alignment accuracy has been improved year by year, and accordingly, it is considered that there are fewer practical problems if a sequence is employed in which the making error of pattern areas of the respective reticles, a mark forming error and the like are measured in advance and position correction is performed during alignment. Further, as is obvious from the pattern separating method in Figs. 12(B) and (C), a light amount during exposure for each of the two separated patterns should be substantially a proper exposure dose for each of the separated patterns. And, resist layer PR can be either of a positive type or a negative type, and it is also effective to use the multiple-focus exposure method together.

[0059] Next, a fifth embodiment of the present embodiment is described with reference to Figs. 13(A) and (B). In recent years, the use of an excimer laser light source has been gathering attention as a light source of a stepper shown in Fig. 3. The excimer laser light source with a high laser gain, like a rare gas halide (such as XeCl, Krf, ArF), is used as a laser medium. Therefore, when a high-pressure discharge is generated between electrodes in a laser tube, a strong light in the ultraviolet range can be stimulated and emitted without a particular resonant mirror. In this case, the spectral of the emitted light is broad and its coherency is low in terms of both time and space. Such a broadband light generates remarkably large chromatic aberration although it depends on the material of a projection lens. In most cases, a projection lens for excimer laser is made of only quartz so as to efficiently transmit a light in the ultraviolet range. Therefore, it is necessary to reduce a spectral width of an excimer laser light

to an extremely narrow width and also to keep its absolute wavelength constant.
[0060] Therefore, in the present embodiment, as shown in Fig. 13(A), a total reflection mirror (rear mirror 201) and a low reflective mirror (front mirror) 205 that operate as a resonator are provided outside an excimer laser tube 202 to slightly increase the coherency, and also two Fabry-Perot etalons 203 and 204 having a variable inclined angle are placed between mirror 201 and mirror 205 outside laser tube 202 to make a laser light have a narrower band. In this case, etalons 203 and 204 are two quartz plates opposed parallel via a predetermined gap, and serve as a kind of band pass filter. Of etalons 203 and 204, etalon 203 is for rough adjustment and etalon 204 is for fine adjustment, and feedback control is sequentially performed while monitoring wavelength variation such that an absolute value of the wavelength of an output laser light is a constant value by adjusting the inclined angle of etalon 204.
[0061] Therefore in the present embodiment, the configuration of the excimer laser light source and axial chromatic aberration of the projection lens as described above are positively utilized and the best image-forming plane is optically moved vertically, and thereby the multiple-focus exposure method is performed. More specifically, when a certain chip area CP is exposed, excimer laser (such as pulse) is irradiated while shifting either of etalon 204 or 203 in the excimer laser light source by a predetermined amount from an inclined angle necessary for stabilizing the absolute wavelength. When the inclined angle of the etalon is shifted, the absolute wavelength is slightly shifted, and accordingly, the best image-forming

plane varies in position in the optical axis direction, in accordance with the axial chromatic aberration of the projection lens. Therefore, by discretely or continuously changing the inclined angle of the etalon while exposure is performed with excimer laser of 50 to 100 pluses, a similar multiple-focus exposure method can be executed without performing any mechanical movement between a reticle and a wafer.

[0062] Fig. 13(B) shows another configuration of a similar excimer laser, and instead of rear mirror 201, a reflective type diffraction grating (grating) 206 serving as a wavelength selecting element is provided so as to be inclinable. In this case, grating 206 is used for rough adjustment during wavelength setting and etalon 204 is used for fine adjustment. For the multiple-focus exposure method, either of etalon 204 or grating 206 is inclined, thereby the oscillation wavelength is changed, and the best image plane is vertically moved.

[0063] As described above, when the excimer laser is used, the image plane (focal position) can be changed using the physical phenomenon that is chromatic aberration, and the chromatic aberration has two aberrations which are a vertical chromatic aberration (axial chromatic aberration) and a lateral chromatic aberration (chromatic aberration of magnification), and the two aberrations are generated simultaneously owing to change in wavelength in some cases. Since the chromatic aberration of magnification means making a projection magnification imprecise, the chromatic aberration of magnification needs to be corrected to an ignorable level. Therefore, as an example, in the case of a projection lens that is both-side telecentric,

a configuration in which a field lens group (correction optical system) for telecentric maintenance arranged on the most reticle side in the projection lens is vertically moved in the optical axis direction is employed, and by vertically moving the field lens group in synchronization with inclination of etalon 204, the chromatic aberration of magnification can be corrected.

[0064] Further, also with a method of adding an offset to the control pressure in projection lens system 16 using together image-forming correcting mechanism 18 shown in Fig. 3, the lateral chromatic aberration (chromatic aberration of magnification) can similarly be corrected. Next, another sequence of the multiple-focus exposure method described previously is described as a sixth embodiment.

[0065] For this sequence, at the stepper shown in Fig. 3, a differential interferometer is provided to measure yawing of wafer stage 26, and irradiates two measurement beams parallel to each other at a constant distance on movable mirror 28x or 28y and measures change in optical path difference of the two measurement beams. This measurement value corresponds to fine rotational error amount that occurs during movement or after stepping of wafer stage 26.

[0066] Therefore, exposure by a step-and-repeat method is sequentially performed at one focal position, with respect to all the chip areas on wafer W. At this point, during the exposure of each of the chip areas, a yawing amount of wafer stage 26 is measured and stored. Then, height change of Z stage 26z or wavelength shift of the excimer laser light or the like is performed, and exposure is sequentially performed from the

first chip area, at the second focal position, in a similar manner in the step-and-repeat method. At this point, the yawing amount on stepping to each of the chip areas and the yawing amount during exposure of the chip area stored previously are compared, and when the difference between the yawing amounts falls within a permissible value, exposure is performed without any correction. When the difference as a result of the comparison is large, rotational correction is made with a θ table that finely rotates while holding wafer W, or correction is made by rotating a θ table that holds a reticle.

[0067] On this operation, while the positional deviation between the reticle and the chip area in the x and the y directions is monitored in a die-by-die method with alignment system 12 or the like, and alignment (positional deviation correction) should be performed on a real-time basis. More specifically, with regard to the alignment error in the x and the y directions, while marks WM1 to WM4 arranged at the chip areas and reticle marks RM1 to RM4 are detected, reticle stage 6 or wafer stage 26 are made to enter a servo-controlled state such that the alignment error is reduced to zero, and at the same time, rotational correction of the reticle or the wafer is performed based on the yawing measurement values from the differential interferometer.

[0068] With such a sequence, the alignment time for each chip area is shortened, and degradation in overlay accuracy owing to errors of chip rotation and wafer rotation can be ignored. Further, the yawing amount of the wafer stage is stored in advance, and therefore, even if the multiple-focus exposure method is used from exposure of a first layer (the first print),

accuracy of overlay exposure by separated reticles is not degraded at all. As described above, in the present embodiment, the focal position is not changed on every exposure of each chip area but the focal position is changed only at the time when first exposure on one wafer is completed, and accordingly, improvement in throughput can be expected.

[0069] While each of the embodiments of the present invention is described above, image intensities of the respective separated patterns inevitably differ because their pattern shapes are different. Therefore, in some cases, a proper exposure dose is different with respect to each of the separated patterns. Accordingly, it is also possible that for each of the separated patterns, a transmittance of a pattern area of the reticle and the like are measured, and a proper exposure dose is determined with respect to each of the separated patterns. Further, reducing the numerical aperture of image-forming light flux during projection exposure also useful for increasing the depth of focus. The numerical aperture of the image-forming light flux can be adjusted in ways such as providing a variable aperture stop plate at pupil EP of the projection lens, or changing the size of the secondary light source image in the illumination optical system by a diaphragm or a variable power optical system or the like. Further, the light flux passing through pupil EP can be restricted into a ring shape (annular shape) by a diaphragm as shown in Fig. 14. Alternatively, the secondary light source image can be formed into a ring shape whose diameter and width are variable or switchable.

[0070]

[Effect of the Invention] As describe above, according to the present invention, finer patterns can be formed.

[0071] Further, the multiple exposures are performed changing the wavelength in excimer exposure and the like, and thereby options for methods of enlarging the depth of focus are increased. These methods are potent methods as solutions for the physical limit of how the depth of focus is increased in lithography not greater than 0.5μm using light. Moreover, the method of separating reticles also leas to the solution for the problem that in recent years the technique to insert a sub-space mark and the like in each pattern has been developed and it has been difficult in terms of space to arrange a main pattern and the sub-space mark together on a same reticle.

[Brief Description of Drawings]

[Fig. 1] A view showing a method of the present invention in a frame format.

[Fig. 2] Figs. (A) and (B) are views showing a state where diffraction lights of a line-and-space pattern and a thinned-out pattern are generated. Fig. (C) is a graph figuring simulation results of image intensity distribution obtained for the line-and-space pattern. Figs. (D) and (E) are graphs figuring simulation of image intensity distribution obtained for the thinned-out pattern. Fig. (F) is a graph figuring simulation results obtained when the image intensities of Figs. 2(D) and (E) are overlapped.

[Fig. 3] A perspective view showing a configuration of a stepper suitable for execution of the present invention.

[Fig. 4] A view showing a state of image-forming in a projection optical system of the stepper.

[Fig. 5] A view illustrating a pattern separating method of the method of the present invention.

[Fig. 6] A view illustrating a pattern separating method of the method of the present invention.

[Fig. 7] A view illustrating a pattern separating method of the method of the present invention.

[Fig. 8] A view illustrating a pattern separating method of the method of the present invention.

[Fig. 9] A flowchart illustrating one exposure procedure using the method of the present invention.

[Fig. 10] A view illustrating a pattern separating method according to a second embodiment.

[Fig. 11] A view illustrating a pattern separating method according to a third embodiment.

[Fig. 12] A view illustrating a pattern separating method according to a fourth embodiment.

[Fig. 13] A view showing a configuration of a laser light source suitable for executing an exposure method according to a fifth embodiment.

[Fig. 14] A plan view showing an annular-shaped filter used to adjust the numerical aperture of image-forming light flux.

[Explanation of Reference Signs of Main Sections]

R, R1, R2, R3, R4	reticles
W	wafer
CP	shot area
PA, PB	whole patterns
PTA1, PTA2, PTA3	separated patterns of PA
PTB1, PTB2, PTB3	separated patterns of PB
2	light source section

4	illumination optical system
6	reticle stage
16	projection lens
18	image-forming correcting mechanism

FIG. 2

(A) -3^{rd} ORDER

-2^{nd} ORDER

-1^{st} ORDER

$+3^{rd}$ ORDER

$+2^{nd}$ ORDER

$+1^{st}$ ORDER

0^{th} ORDER

(B) -3^{rd} ORDER

-2^{nd} ORDER

-1^{st} ORDER

$+3^{rd}$ ORDER

$+2^{nd}$ ORDER

$+1^{st}$ ORDER

0^{th} ORDER

(C) RELATIVE INTENSITY

POSITION (μm)

(D) RELATIVE INTENSITY

POSITION (μm)

(E) RELATIVE INTENSITY

POSITION (μm)

(F) RELATIVE INTENSITY

POSITION (μm)

FIG. 9

START

100: RETICLE ALIGNMENT

101: BLIND SETTING

102: WAFER GLOBAL ALIGNMENT

103: PATTERN NUMBER n = A, CHIP NUMBER m = 1

104: POSITION PATTERN n (RETICLE MOVEMENT)

105: STEPPING TO CHIP m

106: DIE-BY-DIE ALIGNMENT WITH ALIGNMENT MARKS OF CHIP m

107: REPETITIVE EXPOSURE AT A PLURALITY OF FOCAL POSITIONS

108: (m = m + 1)

109: m > 9 ?

110: RESET WAFER STAGE (m = 1)

111: n COMPLETED?

112: CHANGE OF n

END